CHAPTER 6

SELECTIVE WITHDRAWAL STRUCTURES

6-1. Types. Selective withdrawal structures fall into three general types: (a) inclined intake on a sloping embankment; (b) freestanding intake tower, usually incorporated into the flood control outlet facilities of embankment dams; and (c) face-of-dam intake, constructed as an integral part of the vertical upstream face of a concrete dam. The appropriate type of intake structure for a given project depends on a number of considerations including reservoir size, degree of stratification, discharge rates, water quality objectives, need for flow blending between withdrawal levels, and project purposes. Types (b) and (c) predominate at Corps projects. A description of the design and operation of each type is presented by Austin et al. in item 5 (see plate C-44). The most common type of selective withdrawal structure is (b), the freestanding intake. Three general types of freestanding intakes predominate. The first consists of a flood control passage and weirs or ports in a single collection well. This type is generally appropriate for shallow reservoirs with minimum stratification where single weir or port operation is anticipated and blending between intakes is not required. The second is the dual wet well structure which consists of a flood control passage and two collection wells. This type is generally appropriate for reservoirs expected to exhibit strong stratification where anticipated operations for water quality objectives indicate that the capability for blending between intakes is desirable. In both the single and dual collection well systems the selective withdrawal capacity is generally less than the flood control capacity. The third is one through which all discharges, except spillway, can be released. For all types of selective withdrawal structures, the withdrawal device usually consists of one or more ports or weirs, or a combination of the two. The weir(s) can have a fixed elevation or variable elevation.

6-2. Design.

a. State of the Art. Each individual reservoir exhibits unique water quality and hydrodynamic characteristics and therefore it is difficult to provide general information pertinent to the design and operation of outlet structures for water quality control of reservoir releases. Water quality control structures can be used in a variety of situations including single purpose and multipurpose projects. The design of a water quality control structure requires an understanding of the mechanics of stratified flow, water quality and hydrologic considerations, and hydraulic design requirements. A general description of the zone of withdrawal from a stratified body of water for single and simultaneous multilevel releases has been described in item 12. Requirements for water quality and hydrologic investigations necessary to design water quality structures are given in ER 1110-2-1402.[e] Several examples of physical and mathematical model studies that have been conducted to design water quality structures from a water quality and hydrologic standpoint are given in items 26, 27, 28, 36, 61, 62, and 67. The principles of design given in this manual apply to the hydraulic design of water quality structures. Many needed design principles have yet to be established and in many cases, economic considerations dictate the design. This section summarizes a number of designs and design problems that have been investigated with physical models.

b. Design Information. Water quality outlet structures naturally divide into three parts: (1) inlets and collection well(s), (2) control gate passage(s), and (3) exit passage(s). Presently available pertinent design information is summarized in the following paragraphs.

(1) Inlet Ports. The capacity of ports and collection wells is based on water quality and hydrologic considerations. Additionally, the port size and geometry affect selective withdrawal characteristics. Inlet ports to water quality collection wells are designed to operate fully open or closed. Total flow is regulated by a downstream control gate. Ports should be operated under submerged flow conditions. Free flow conditions should be avoided. Ports are generally placed directly facing the upstream direction. Placing inlet ports vertically above each other can result in interference of operating equipment. Port velocities primarily affect trashrack design, flow stability, and collection well turbulence. Velocities of 4 to 6 fps or lower are recommended for normal operation, but designs with velocities up to 20 fps may be possible with hydraulic model studies (item 68) of conditions where fine control of selective withdrawal is not a governing consideration. Inlet ports operating under appreciable submergence with relatively low velocity can be expected to be cavitation-free. However, their entrances should be bell-mouthed for efficient inflow conditions. The entrance curves terminate possibly with a short tangent section at the inside vertical walls of the collection well where the gate is located. Inlet ports should be provided with trashracks to prevent debris from entering the collection well. Since inlet port gates are not normally subject to cavitation pressures, they do not require venting. Upstream bulkhead slots or other provisions for maintenance and repairs are required. These slots may also be used for trashracks.

(2) Inlet Weirs. An inlet port that is not totally submerged

can be operated as an inlet weir provided sufficient flow constriction is maintained by a downstream control gate so that submerged weir flow results. Without sufficient flow constriction, flow control may shift between the inlet weir and the control gate, causing a flow instability. Inlet weirs should always have trashracks to prevent debris floating on the water surface from entering the structure. If the release of surface water is desired most of the time, a structure may be designed to be operated specifically as an inlet weir. The crest of such a weir is usually thin and vertical, thus allowing movable bulkheads or a selector gate (variable position, mechanically actuated gate) to serve as a movable weir so that upper pool releases can be made for varying pool elevations. The weir flow should be submerged with flow control maintained downstream. Entrance velocities should be within the range of 4 to 6 fps and are normally governed by selective withdrawal considerations. The depth of flow over the weir and the weir length are sized to provide the required discharge and release water quality objective.

(3) Collection Wells. Collection well geometry and size are dependent upon the number, size, and spacing of inlets and vary appreciably from project to project. The primary purpose of a collection well is to provide a tower facility for the inlets and their gates. The collection well also serves as a junction box where the flow direction changes from horizontal to vertical to horizontal. Sometimes the flow direction changes can result in appreciable surging and head loss. Equipment in the collection well should be securely anchored. Damage to ladders in the collection well at Nolin Dam has occurred with 2- to 5-ft surges occurring with a 3-ft head differential from the pool elevation to the water-surface elevation in the wet well. Head losses that normally occur in the intake are the intake loss, velocity head through the inlet, friction in the well, entrance loss to service gate passage, and the velocity head of the vertical velocity in the well when the service gate passage is at an angle to the collection well. Blending of flows for water quality purposes should be done by blending flows from separate wet wells in a dual wet well system. Each wet well should have individual flow control, and inlet(s) at only one elevation should be open in each wet well. Experience has shown that erratic blending due to flow instability between inlets in separated wet wells may occur where the wet wells are connected and only a single service gate and gate passage are provided for flow regulation.

(4) Outflow Passages. Water quality outflow passages are usually very short and operate with free-surface flow except sometimes for the maximum design flow. In concrete gravity dams they may be located in the nonoverflow section and discharge through the sidewall of the stilling basin (plate C-45). They may also be located on the

upstream face of the dam and discharge onto the spillway. Water quality facilities for embankment dams are most frequently incorporated in the intake towers of the flood control outlet works and discharge into the flood control conduit. In multiple flow passage flood control intakes, the water quality releases can be made through the intake dividing pier (plate C-46), through bypass pipes around the service gate (plate C-47), or through the emergency gate well (plates C-47 and C-48). In the latter case, the flood control service gate is used to regulate the water quality flow release discharge.

(5) Submerged Weirs. Submerged weirs upstream of outlet works (plate C-49) can be used to prevent withdrawal of bottom waters from reservoirs by flood control conduits and penstocks (items 11 and 32). The principles involved have been studied and reported by WES (item 12). Local topography, flow requirements, and adjacent structures have appreciable effect upon the performance of these weirs. Therefore, a model study to determine the selective withdrawal characteristics is recommended where an upstream submerged weir is included in the project design.

6-3. Flow Regulation. Flow regulation is accomplished by means of a control gate(s) located in a uniform conduit section(s) downstream from the collection well(s). The gate passage section can be connected to the bottom of the collection well by a bell mouth or by a long radius elbow. In either case, pressures in this transition should be carefully studied in accordance with guidance in paragraph 2-16. Since the gate normally operates under little or no back pressure, it is essential that the issuing jet be adequately vented. Discharging the gate jet into an enlarged section with venting all around should be considered. Venting should be provided in accordance with the guidelines presented in paragraph 3-17.

6-4. Model Investigations.

a. Concrete Gravity Dams. A water quality outlet design for a concrete gravity dam is shown in plate C-45. Qualitative model tests of this design were made at WES (item 1). The location of the water quality tower adjacent to the left abutment of the spillway resulted in undesirable flow contraction around the tower with spillway flows in excess of 25,000 cfs. Preliminary tests of the water quality inlet orifices indicated that their elevation and size were not capable of meeting the required withdrawal characteristics. Model tests were also conducted on the multiple penstock intake structure at the proposed Dickey Dam (plate C-50). These tests were conducted to determine the selective withdrawal characteristics of this structure (item 26). The Dickey Dam will consist of two earthen embankments with the multiple penstock intake structure located in the concrete gravity section. The intake structure will have individual collection wells connected to each of five 27-ft-diam penstocks. The level of withdrawal of flow into the collection wells will be controlled by the location of the top of the movable selector gates. The selector gates will function as a variable crest elevation submerged weir.

b. Embankment Dams. Five model-tested earth dam water quality control structure designs are shown in plates C-46, C-47, C-48, C-51, and C-52. The Beltzville design (plate C-46) releases the water quality flows into the flood control conduit through an outlet with its exit portal in the nose of the dividing pier of the flood control intake tower. At New Hope Dam, renamed B. Everett Jordan Dam, (item 70), the emergency gate well serves as the water quality collection well (plate C-48). The flood control regulating gate serves as the water quality regulator. When the emergency flood control gate is closed, water quality releases pass from the collection well into the flood control gate passage and under the regulating gate. Model tests showed the need to limit service gate openings to a maximum of 34 percent of fully open for water quality releases to prevent serious negative pressures in the throat section between the collection well and the flood control gate passage. The Taylorsville design (plate C-47, and item 25) has dual collection wells similar to the New Hope (B. Everett Jordan) design. During selective withdrawal operation, the emergency gates will be closed and flow will be discharged through the multilevel intakes into the wet wells and through an opening or throat located in the roof of the gate passages between the emergency and service gates. The service gates will be used to regulate the selective withdrawal releases. Additionally, an 18-in.-diam pipe bypass around each service gate will be provided to regulate the release of low flows with the service gates closed. Similar to the model tests of the New Hope (B. Everett Jordan) structure, tests of the Taylorsville structure also showed the need to limit service gate openings for water quality releases. For the Taylorsville structure, service gate openings greater than 55 percent of fully open resulted in negative pressures in the throat section. The DeGray design (plate C-51) consists of a single four-sided intake tower equipped with multilevel openings and a cylindrical gate (item 14). This structure provided selective withdrawal capability for both flood control and hydropower releases. The tower has two bulkheads and a trashrack in a single set of gate slots in each of its four sides. Placement of the trashrack panel determines the withdrawal elevation. The cylindrical gate in the intake tower is not operated as a flow control device. Flow passes vertically from the intake tower through a 21-ft-radius elbow into a 1205-ft-long, 29-ft-diam conduit. The conduit is bifurcated to provide for flood control and power generation releases. The flood control releases are regulated at the end of the bifurcated conduit so that releases for both flood control and power generation can be drawn concurrently through the intake tower. Model tests were conducted on the water quality outlet structure at Beech Fork Dam (plate C-52) primarily to evaluate the effects of local terrain on the water quality performance of the outlet works (item 42). The structure has dual collection wells, each with 30-in.-diam conduits and control valves that release water quality flows into the flood control conduits immediately downstream of the flood control service gates.